How to identify *potential* climate trends in short-term satellite (and related) data sets available in DICCE-Giovanni

One of the difficulties that can arise when using Earth-observing satellite data sets for teaching and learning about climate change is that most satellite data sets only extend back to the 1990s. There are a few exceptions, such as for stratospheric ozone and atmospheric temperature. The main reason is that the “era” of Earth observing satellite missions that collected data useful for studying different climate processes began in the late 1970s and 1980s, but most of the instruments that collected data available now were launched in the late 1990s or early 2000s.

This means most of the actual satellite data sets in DICCE-Giovanni are only 10-15 years long. DICCE-Giovanni also has some longer data sets from models and weather stations. Some of these data sets start in 1979 and a few of them, with useful climate-related data like rainfall, even go back to the middle of the 20th century.

Many climate scientists think it takes at least 30 years of data to find candidates for actual climate change trends. They think it takes this much time for a change in one direction (which can be called the climate change “signal”) to be detectable, because there is always going to be year-to-year and month-to-month variability (which can be called the climate “noise”). In order for the climate change signal to be observed, it has to be large enough to be distinguished from the noise.

A factor that has made it more difficult to detect climate trends in the period from about 2000-present is that there has been a slowdown in the rate that the surface of the Earth is warming, compared to the previous decades. Trends that seemed apparent before 2000 are not as discernible now because the increasing temperature that was driving the changes has not been as strong. Scientists are still working on determining the main causes of this slowdown, which seems to be due to a combination of several factors in Earth’s environment.

So, identifying potential climate change trends during this period of satellite data may require some background information. To start, climate change is not happening uniformly over the entire Earth. In general, the polar regions are changing faster than other regions. <u>So it can be easier to find larger changes in the polar regions</u> for such variables as temperature, sea ice cover, cloud cover, and vegetation. There are several factors that are causing the polar regions to be the regions of greatest change. Many models of climate indicate that the poles will warm faster, an observation called “polar amplification”, which involves heat exchange with the polar oceans. Furthermore, the polar regions are changing faster because in those regions, temperatures increasing from increased carbon dioxide in the atmosphere are causing surface snow and ice to melt. That melting changes the color of the surface from white to other colors. Whereas white simply reflects solar radiation, those darker colors absorb some of the radiation and emit it in all directions as heat, thereby enhancing the carbon dioxide-induced temperature increases. Open ocean areas also allow increased warming of polar oceans compared to areas that are covered with sea ice. With dramatic melting of snow and ice has come dramatic changes to the amount of landscape that is permanently frozen and to the types of vegetation that thrive there.

Another important climate variable that is changing with climate change is precipitation. The general understanding of how precipitation will change as the Earth warms is that the coastal areas of the continents may get more intense, yet fewer, precipitation events – whereas inland areas will simply get less precipitation. This will be mainly due to the fact that warmer air temperatures raise the capacity of the atmosphere to hold more water vapor, thus reducing the number of occurrences in which the air temperature drops enough to cause condensation. So, for example, if an area-of-interest on a continent includes both the coast and the interior, then any actual trend of decreasing overall precipitation inland could be obscured on the coast by either a trend of no overall change at all, or increasing intensity of the precipitation during those times when it does fall. Separately examing the coast or the interior potentially reduces the potential for conflicting data that could minimize or obscure trends. So it is usually a better practice to look for climate change trends in smaller regional areas than in larger areas. If the climate trend is prevalent over the entire area, it will very likely be apparent in the smaller area, too.

Another way to find potential climate change trends is to examine what can be called "marginal" or "boundary" areas. Boundaries between different climate zones can move rapidly in response to changes, while the central parts of these areas won't change as much. A classic example is the Sahel region in Africa, which is the southern boundary of the Sahara Desert. The Sahel is an area where precipitation and temperature can vary substantially over a small area, and this variation can move the boundary between moist and dry conditions a significant amount.

Other marginal areas are mountain ranges, where temperature and moisture and even solar radiation can vary over short distances due to changes in altitude. Farmers, for example, are concerned about the implications of changes in their local climate on crops they grow on mountain slopes, like coffee, tea, grapes (for wine), and some grains, like barley.

One other way to look for potential climate change trends is to look for changes in the timing and strength of events, particularly those related to the seasons. There are many studies showing that in the spring, the ice on lakes is thawing sooner, flowering plants are blooming earlier, and the peak in spring snowmelt is occurring sooner and peaking faster. Likewise, the change in temperature that produces the autumnal color spectrum on deciduous trees is occurring later in the autumn, and the ice on lakes and rivers is freezing later, too. The monsoon in India has been reported to be less reliably timed in recent years, and is also not delivering as much of the heavy rainfall that is its normal state. Such changes might not be apparent when looking at every month in a data set, but might become more obvious when just comparing the months when conditions are the most changeable.

It should be noted that even if recognizable climate change trends are not found when using the understandings described above, applying these analyses is essentially what climate scientists are doing. Polar regions, boundary areas, small regions with defined climate norms, and observations of seasonal timing changes are the "hot spots" of climate change, so examining them and determining their current state is very useful, even if a definite trend cannot be identified in the data.

Examples of each of these “search areas” for climate change trends are shown below.

The Arctic Ocean

A prominent change in the Arctic Ocean has been the decline of sea ice cover in the summer. Using the *Fraction of Sea Ice* data product, an area in the Beaufort Sea (north of Canada and Alaska) was used for a time-series plot. The decline of sea ice cover in the summer can be seen as the points which descend toward lower and lower fractional values at approximately yearly intervals, starting about 1998. Figure 1 displays the time series.

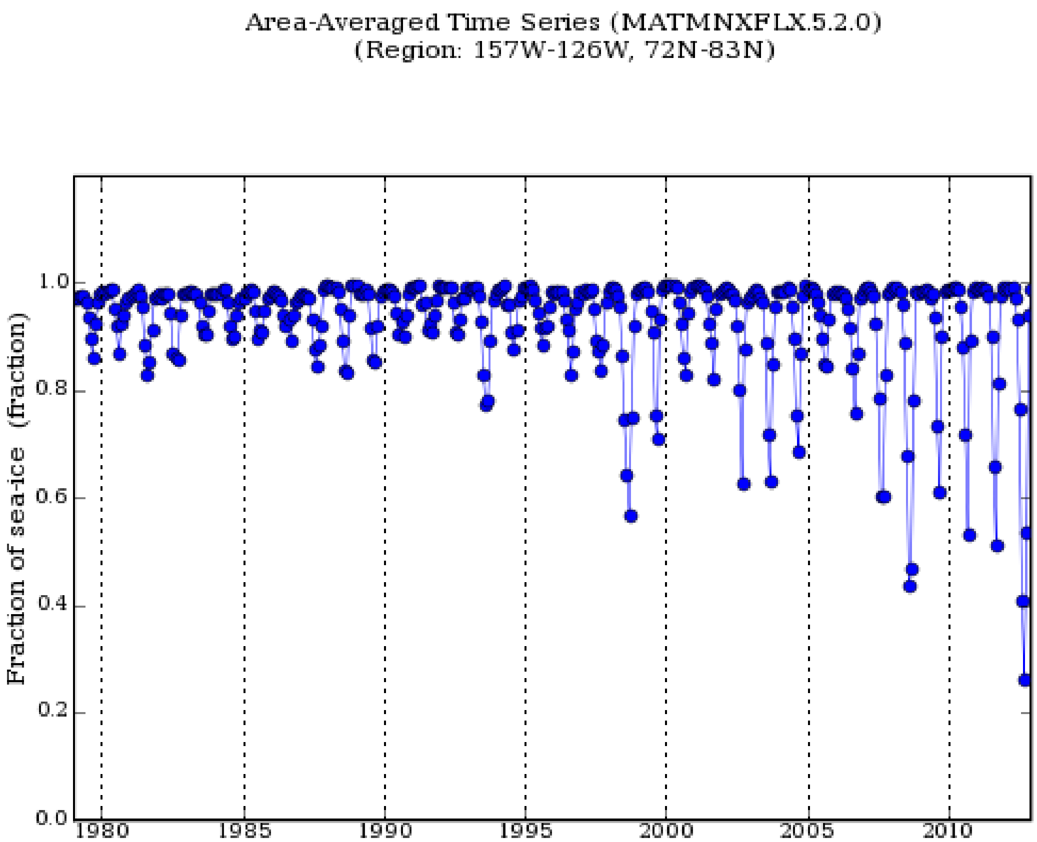

Figure 1. Time Series of fraction of Beaufort Sea covered by ice. The area covered by sea ice declines in the summer months starting about 1998.

Temperature in the Foothills of the Himalayas

Figures 3-6 show time-series plots of surface temperaturein the the foothills of the Himalayas. This is is a mountain area where climate change impacts might be detectable. The area selected for analysis is shown in Figure 2. This particular area includes Darjeeling, India, which lends its name to a famous variety of tea that is grown at altitudes between 800-2000 meters, with the higher altitudes considered to yield the finest quality of tea. (http://www.teagschwendner.com/US/en/Tea_Growing_Regions.TG)

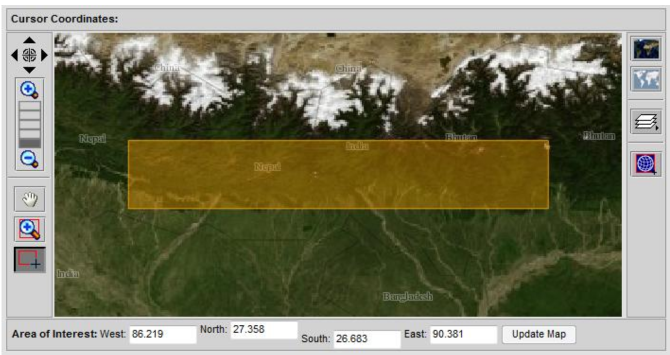

Figure 2. Area of analysis in the Himalayan foothills.

The data for this plot were imported from Giovanni into Excel for further analysis. As you can see in Figure 3, when all the months from January 1948 to December 2010 are plotted, a temperature trend is not apparent.

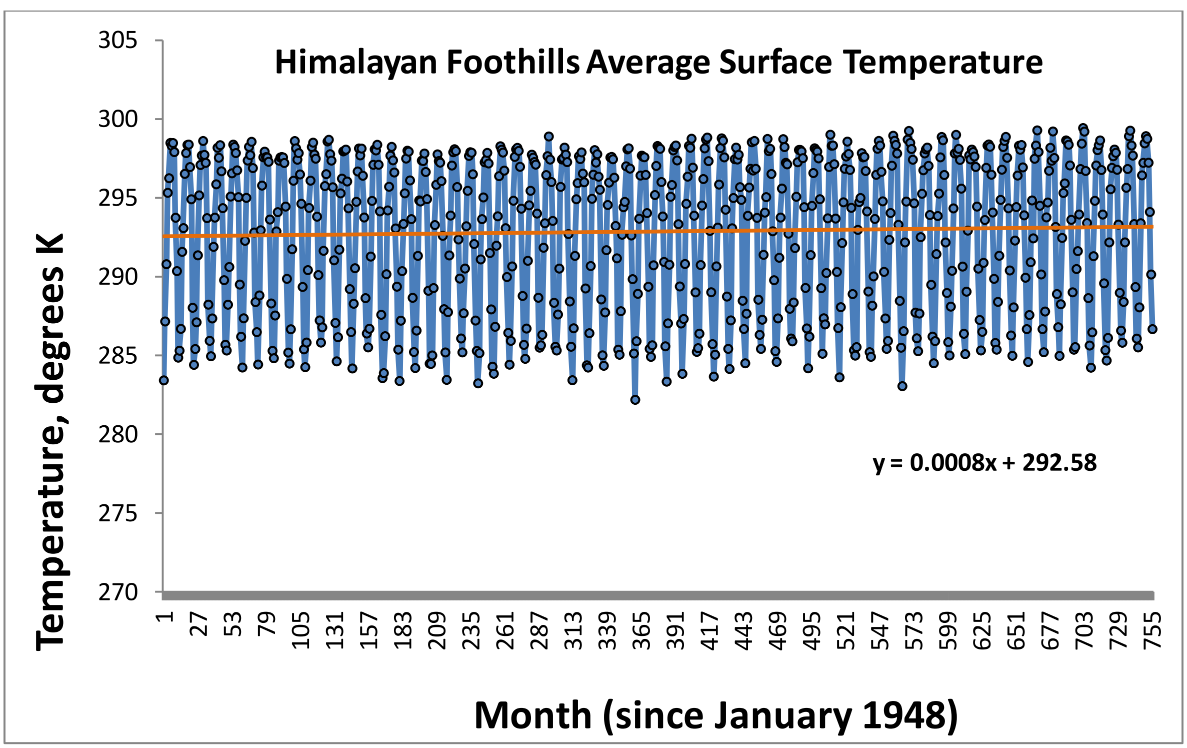

Figure 3. Each month's average surface temperature in the Himalayan foothills since 1948.

However, close examination of these data indicate that there might be a noticeable change in the highest and lowest temperatures.   So in an Excel spreadsheet, the data were extracted by month, and then plotted for individual months. Shown below are the data for August, February, and May.

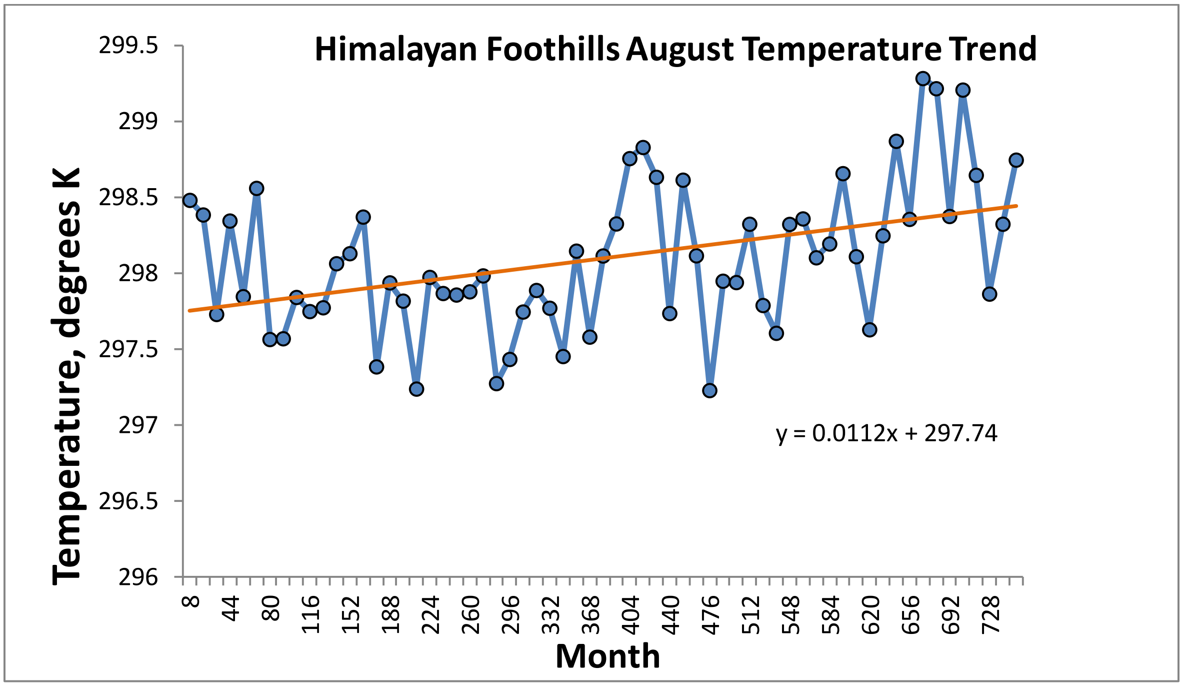

Figure 4. Average surface temperatures in the Himalayan foothills each August since 1948.

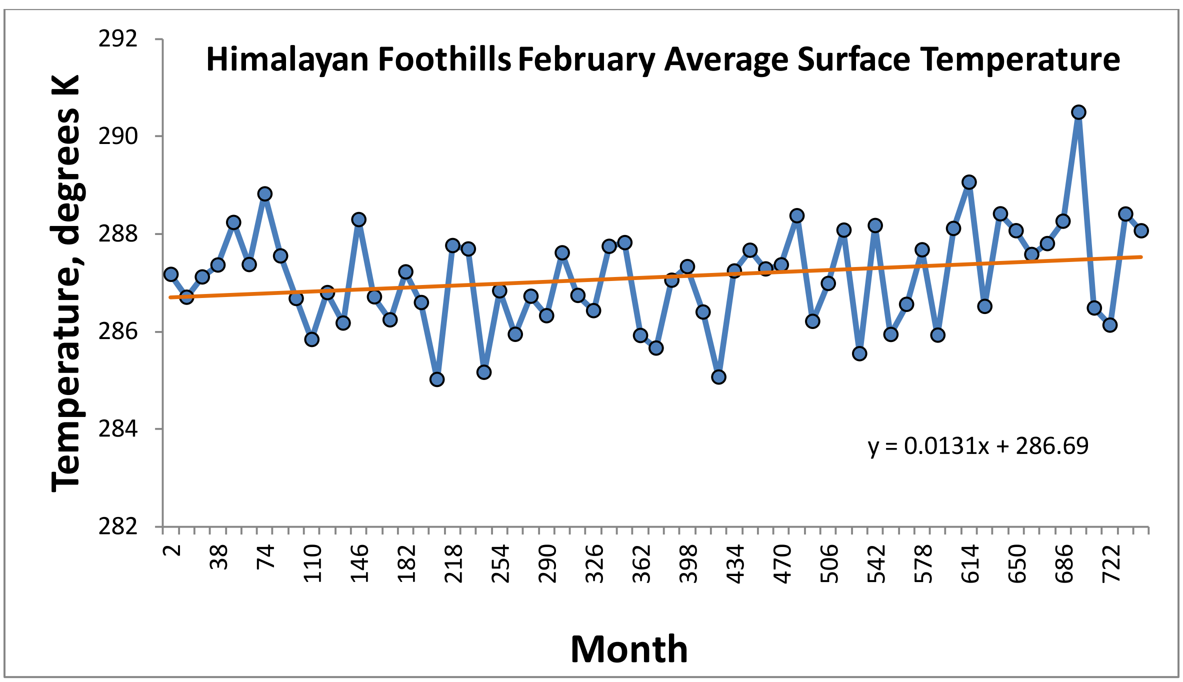

Figure 5. Average surface temperatures in the Himalayan foothills each February since 1948.

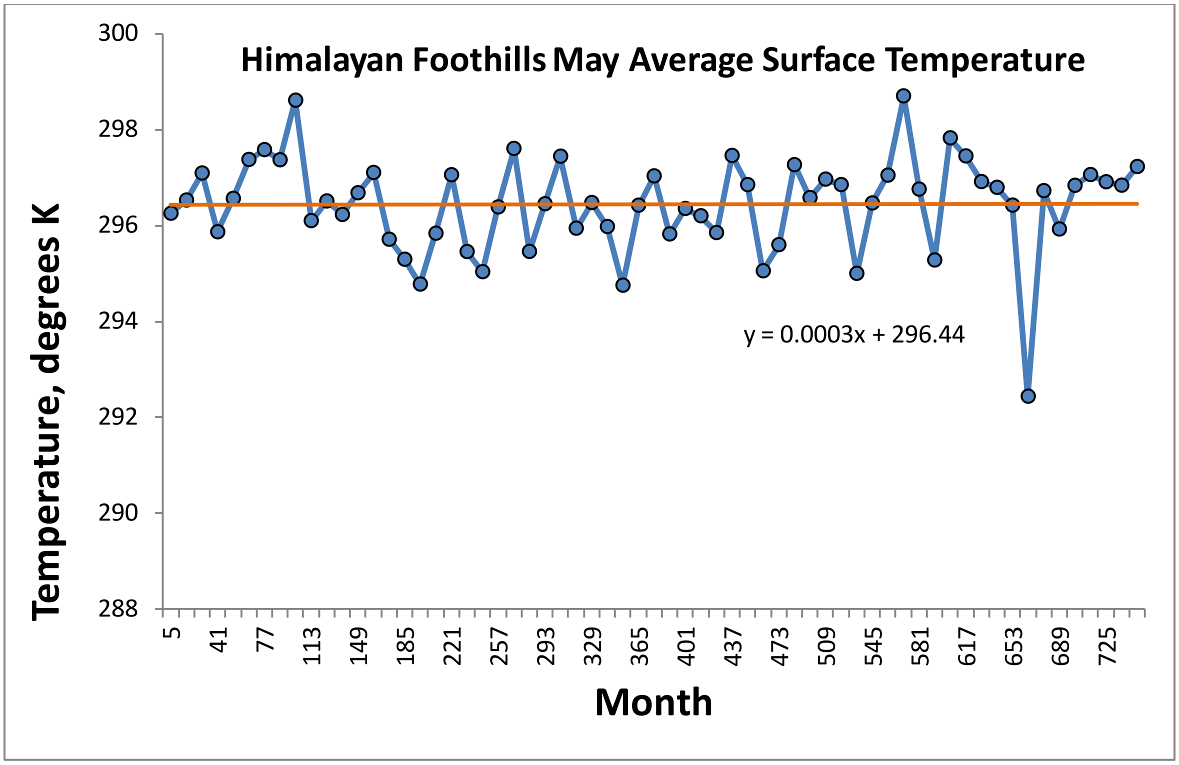

Figure 6. Average surface temperatures in the Himalayan foothills each May since 1948.

These plots show that there are distinct trends during the height of summer and depth of winter, when conditions are more stable, than during the variable period in spring when conditions can change more rapidly. This explanation makes sense statistically. For example, if most temperatures at a particular Earth location in January hovered around 30°F in 1948, and broad annual temperatures increased 1°F at that location between 1948 and 2014, that increase of 1° over the years would be relatively easy to detect as a trend because there would likely have been fewer unpredictable swings in daily temperature variances than would be the case in transitional fall or spring months. Hence, in a spring or fall month, a broad 1° increase will be less obvious because the more widely swinging daily variation will mask the predictability of the kind of trend that would be detectable on a time-series plot.

Whether or not the trend is obvious on a time-series plot, the predictably, consistently warmer temperatures in peak summer and winter months can affect agriculture by influencing the amount of water that crops need, their tolerance for warmer temperatures, and the growth of organic pests that might harm them. Increasing temperatures in winter may lead to less snow accumulation and earlier melting of whatever snow that manages to accumulate.

Even though not much of a trend in warming temperatures is discernible in the May data in Figure 6, scientists have documented other seasonal changes around the world, such as indicators of spring occurring earlier in the year. Examples of these indicators include the thawing of the ice on lakes and rivers, the increasing runoff in streams and rivers due to snowmelt (called the spring “freshet”), and the blooming of flowers. Though such indicators of spring are quite variable, the research shows that broadly speaking they are occurring 7-10 days earlier than they were a century ago.

Precipitation in the Sahel

The extended time-series in Figure 7 shows the variability of rainfall in the Sahel. Figure 8 shows the geographical area. Extended dry periods, such as are evident in the late 1970s and early 1980s, can lead to famine and starvation in this region. Note the general decline in rainfall commencing from the late 1960s, but also note that there were exceptional months when the rainfall spiked upward, perhaps due to short changes in wind patterns or ocean currents off the African coasts.

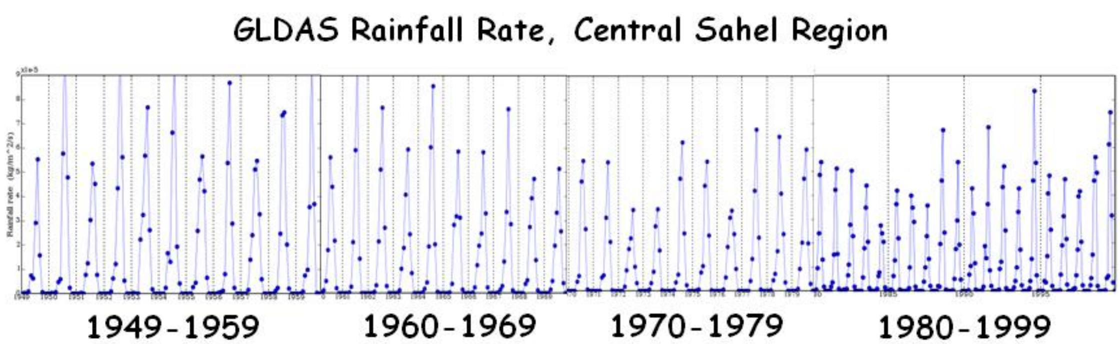

Figure 7 (top) and 8 (bottom). Time-series plot of rainfall and map of the Sahel region-of-interest.

Snow cover in the Midwest

As the Earth gets warmer, one prediction of seasonal change would be the loss of snow cover on the ground due to melting. In some areas that are subject to “lake effect snow”, it is predicted that there will be more snowfall because warmer temperatures will bring about less (and later) freezing of the lakes during winter months, and more evaporation from exposed warmer water. The evaporation will cause an increase in humidity and greater snowfall when the colder air in the troposphere gets saturated with water vapor and condenses. Even if there is more snowfall, however, the snow on the ground could melt faster, leaving less snow cover on the ground that persists long enough to provide water for the humans, plants, and animals in the watershed.

An area of the U.S. Midwest illustrates this possibility, and the MERRA fractional snow cover data product in DICCCE-G was used for the analysis. Figure 9 shows the area on a map and Figure 10 shows the time-series plot. Note that this data product goes back to 1979. It is possible to look at this time-series, note when the satellite era begins in the 1990s, and realize that discerning a trend here for the shorter period would be more difficult. This time-series shows a general decline in snow cover during the winter (which provides the higher values of snow cover). The actual data could be examined in a spreadsheet or DICCE-G table to get a better visual sense of whether there are more marked declines on the winter “shoulder” months of November and March, due to warmer late autumn and early spring temperatures.

Figure 9. Midwest region-of-interest for the snow cover analysis. Lake Michigan is at top right; snow on the Colorado Rocky Mountains can be seen at center left.

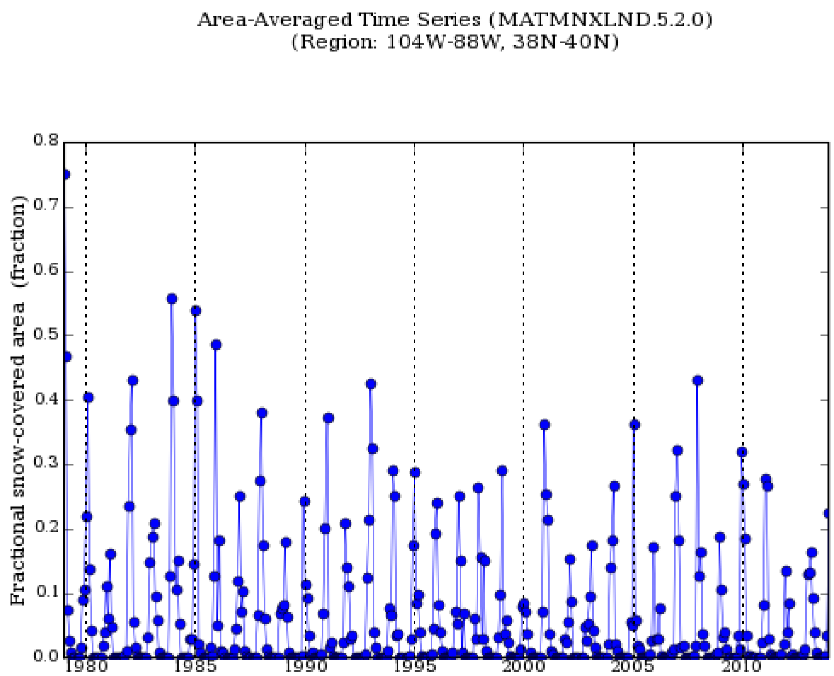

Figure 10. Time-series plot of fractional snow-cover values for the region-of-interest in the U.S. Midwest shown in Figure 9.